COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

April, 1945

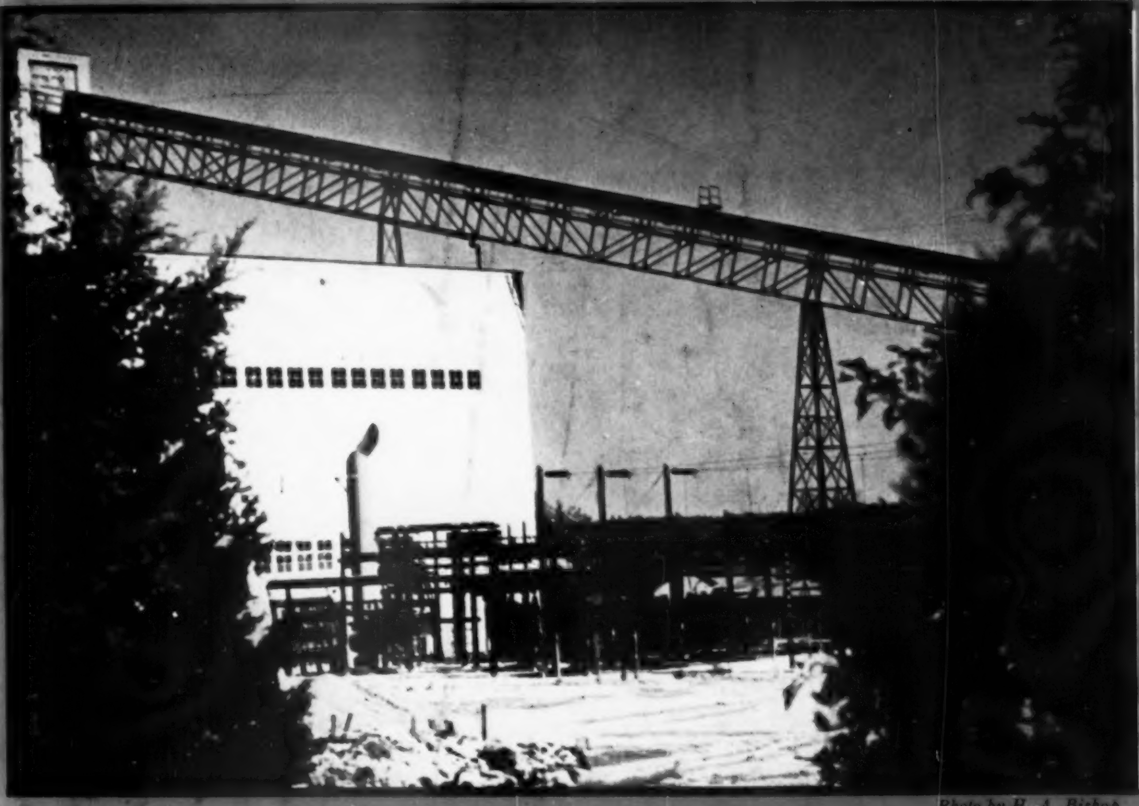


Photo by H. A. Bishop

Standards for Large 3600-RPM Steam Turbine Generators ▶

Causes and Prevention of Overheated Grates ▶

Boiler Operation at High Altitudes ▶

Present day TRENDS in UTILITY Steam Practice

as reflected in design characteristics of recent C-E Units

Unit installed in

CHESTERFIELD STATION

Virginia Electric & Power Company

Chesterfield, Virginia

PRINCIPAL DESIGN CHARACTERISTICS

A 3-drum boiler with large rear top drum providing ideal conditions for final steam cleaning and separation.

B Two-stage superheater with widely spaced tubes in first stage permitting low gas velocities and thus minimizing slag accumulation. Boiler and superheater surfaces in this area completely accessible for cleaning.

C Vertically adjustable burners permitting control of gas temperatures entering boiler and superheater and providing primary control of superheat temperature.

D Thermostatically controlled by-pass damper which provides final close control of superheat temperature.

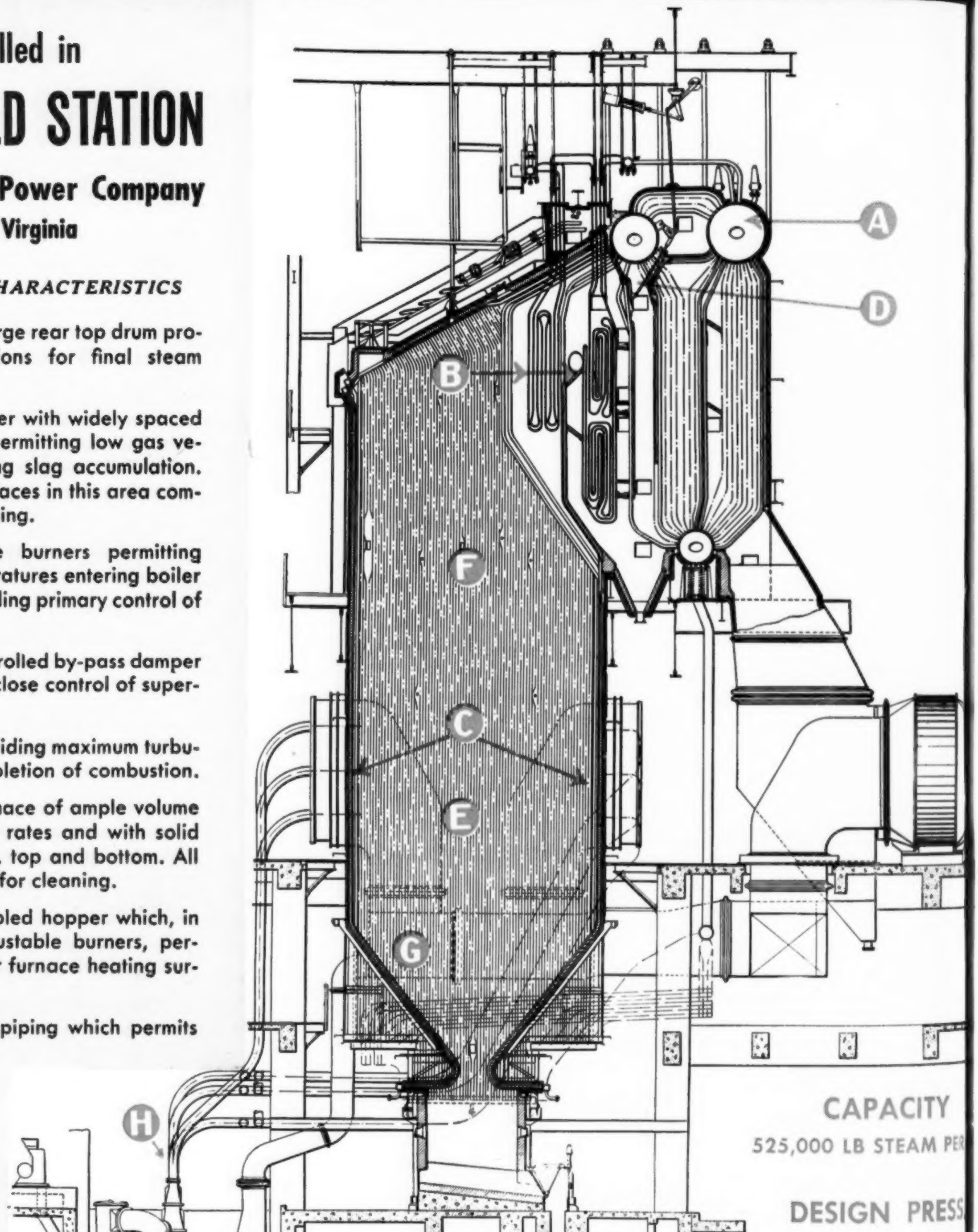
E Tangential firing providing maximum turbulence and rapid completion of combustion.

F Simple, clean-cut furnace of ample volume for low heat release rates and with solid metal surfaces on all sides, top and bottom. All surfaces readily accessible for cleaning.

G Completely water-cooled hopper which, in conjunction with adjustable burners, permits full utilization of lower furnace heating surfaces.

H Arrangement of mill piping which permits each mill to supply fuel to all four corners of furnace.

J C-E Raymond Bowl Mills provide quiet, dependable, low-cost operation — advantageous air-flow conditions for direct firing — fine grinding with low percentage of coarse particles. Permits use of high air temperatures for mill drying. A-867



COMBUSTION C-E ENGINEERING

200 MADISON AVENUE NEW YORK 16, N. Y.

C-E PRODUCTS INCLUDE ALL TYPES OF BOILERS, FURNACES, PULVERIZED FUEL SYSTEMS AND STOKERS; ALSO SUPERHEATERS, ECONOMIZERS AND AIR HEATERS

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SIXTEEN NUMBER TEN

CONTENTS

FOR APRIL 1945

FEATURE ARTICLES

EDITORIAL

DEPARTMENTS

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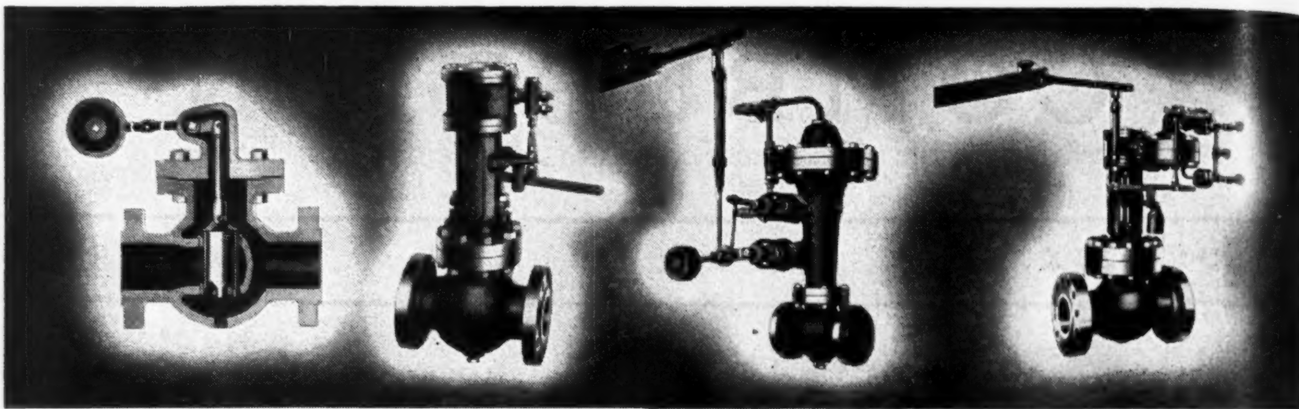

Copes Valves for simple level control. Left, direct-operated. Right, relay-operated.

Copes Flowmatic Valves for steam-flow water-level control. Left, direct-operated. Right, relay-operated.

EDITORIAL

Enemy Patents

Digests of enemy patents, which are now vested in the Alien Property Custodian, are being issued for the information of those who might be desirous of exercising the privilege of wartime license at a nominal fee of $15. These patents, mostly German, have been filed from time to time with the U. S. Patent Office. The wartime licenses are good for the life of the patents, but six months after the conclusion of hostilities royalties will be subject to negotiation, presumably under some pattern to be prescribed by the Government.

There are about forty-five thousand of these enemy patents covering numerous fields, a substantial share of which deals with chemical and mechanical engineering. For convenience, the digests are grouped into various subdivisions of the fields covered. One recently issued group contains some three hundred patents on steam-generating equipment, another group covers fuel-burning equipment, and still another, prime movers.

A perusal of these patents is most interesting in showing the German approach to the solution of numerous problems that have been encountered and met differently on this side of the Atlantic. As might be expected, many ingenious designs and arrangements are revealed, but, in general, they involve greater complication than is to be found in American practice without offering any apparent advantages. Therefore, it is doubtful if many licenses in the power plant field will be taken out under the present arrangement. In some other fields the situation may be different.

"War Time" Still Warranted

There has been considerable agitation by certain groups during the past few months toward abandonment of "war time" and pressure was brought upon a number of state legislative bodies to enact bills re-establishing standard time. Influence of the Office of War Utilities is generally credited with having successfully blocked such attempted legislation, but an early defeat of Germany is certain to revive this agitation. However, immediate action in most cases would be forestalled by the fact that many of the legislatures have now adjourned.

One contention advanced in support of the recent "curfew" was that it would mean a saving in electricity, but this appears to be generally discounted as a major item and is not at all comparable with the savings that have been effected through "war time" which applies to everyone and to every locality.

Authentic figures for the whole country are lacking as to annual fuel savings that have resulted from advancing the clocks an hour, but reports have been given out from time to time concerning regional savings. For instance, H. P. Liversidge, President of the Philadelphia Electric Company, in speaking recently before the local A.S.M.E. Section, stated that in the area constituting the power pool for New Jersey, Delaware, eastern Pennsylvania, Maryland and the District of Columbia, "war time" had cut down the winter peak by 200,000 kw and had effected an annual saving of more than 70,000 tons of coal. In Chicago alone the shift in time was reported to have reduced the winter peak by some 80,000 kw, and fuel savings for the whole country have been variously estimated as between 300,000 and 500,000 tons by utilities alone. If industrial plants and buildings generating their own power be added, the figure would be considerably amplified.

The need for fuel conservation is now as urgent as it was when "war time" was adopted. The Solid Fuels Administration estimates that, even without any stoppage in coal production, the output of bituminous coal this year would fall short some forty million tons of meeting the demand. An early termination of war with Germany would result in some cut back in war production but this would likely be offset by increased civilian production and aid to Europe, so that the total fuel demand would remain close to the predicted figure.

Although "war time" is only one of a number of measures adopted to conserve fuel in this critical period, its contribution has been sufficient to outweigh arguments against its continuance until normal times have returned.

Engineering Programs

Cancellation of practically all engineering meetings, other than those of local character, in conformance with ODT regulations, has imposed new problems on program and papers committees. Several of the national societies are endeavoring to continue the usual solicitation of technical papers with the idea that these will be made available to the memberships through publication and that written discussion can be stimulated. This procedure makes no difference to members who are not in the habit of attending national and regional meetings, but those that have been accustomed to do so will miss the personal contacts and impromptu discussions.

Already there have been indications that, without the meetings, dead-line dates for the completion of papers are likely to be disregarded; also that fewer papers will be forthcoming. Judging from some of the crowded programs of later meetings, the latter may be welcome if it results in concentration on only the best and most timely papers.

Relief from the ODT regulations is not probable during the present year, inasmuch as the shifting and return of troops after the defeat of Germany will impose still greater burdens on transportation; hence relatively long-range planning will be necessary on the part of the committees.

Standards for Large 3600-Rpm Steam Turbine-Generators

By A. G. CHRISTIE

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A review of the recently approved standards for condensing turbine-generators of capacities above 10,000 kw, together with a discussion of these standards as to capability, sizes, steam and extraction conditions and generator ratings. The economics of such standards are cited.

IN 1938 the National Defense Power Committee undertook the standardization of large steam turbines. A Sub-committee representing the turbine-generator manufacturers, the public utilities and the Government adopted and published "Preferred Standards for Steam Turbine-Generators of 10,000-Kilowatt Rating and Above." These Standards were prepared with a view to expediting the production and reducing the costs of such equipment. Standards of throttle pressure and temperature, voltage, power factor and other technical details were recommended for nine sizes of condensing turbines and eight sizes of superposed units ranging from 10,000 to 100,000 kw, fifteen of the units being for 3600 rpm operation and two for 1800 rpm. The Committee recommended that the Standards should, as occasion warranted, be reviewed to determine whether advances in the art call for specific modifications.

In July 1941, the National Electrical Manufacturers Association issued its "N.E.M.A. Turbine-Generator Recommended Practices," with operating characteristics and fourteen standard ratings from 500 kw to 7500 kw, inclusive, and with a full line of 3600-rpm, 80 per cent power factor generators. This provided for a wide range of standard machines for industrial application.

The art of steam station design advanced after 1938 and the standards of that date were not entirely acceptable to engineers planning new installations. Practice in extraction feedwater heating varied widely among users of steam turbines and extraction provisions specified by the Standards were not adhered to by purchasers. This required changes in staging and in the construction of turbine casings. Turbine designs thus tended to become "tailor-made" jobs and the gains expected of standardization were not attained. Recognizing this trend the Power Division of the A.S.M.E. arranged a Panel Discussion on Extraction Feedwater Heating at the Society's Annual Meeting in December 1942, when various points of view were presented. The discussion at this session indicated that the differences between the various arrangements of extraction points were of a small order provided the temperature from the last heater was the same in every case. Also, the number of heaters and the final feed temperatures are fixed by the use and size of economizer sections of the steam generators. The discussion indicated that standard extraction temperatures were possible and would expedite the construction and delivery of turbine-generators. A resolution was passed requesting the Council of the Society to appoint a committee for further study of the standardization of steam turbines.

The New Revised Standards

The Council of A.S.M.E. authorized this committee. It was apparent that the cooperation of the electrical engineers would be necessary in the fixing of standards and the Board of Directors of the A.I.E.E., was asked to appoint representatives to serve on a Joint Committee on turbine-generators.

The Joint Committee undertook to establish certain standard ratings and characteristics for large condensing units operating at 3600 rpm which would be best suited to the needs of purchasers. Throttle pressures and temperatures were chosen for each selected size of turbine-generator. The number of extraction openings to be provided on each casing and the saturated temperature at each opening when operating at rated load and with all extraction heaters in service, were also selected. It is believed that general acceptance of these standards should result in lower first cost and more prompt deliveries of standard turbine-generators, than for non-standard units.

It was not the intention of the Joint Committee that these Standards should interfere in any way with the further development of turbine-generators. Rather, the Committee recommends that the Standards be reviewed periodically or as technical and economic developments warrant changes.

In arriving at these Standards, the Joint Committee had the benefit of advice and information from technical committees of the A.S.M.E., A.I.E.E., A.E.I.C. and E.E.I. In this manner valuable data and assistance were received from operating companies with more than 18,000,000 kw of steam turbine-generator capacity on their various systems.

The adoption of these Standards will in no way prevent the purchase of any size of turbine-generator that is desired for any operating conditions different from those indicated in the Standards. Such units, however, may not have the benefit of lower first cost and the shorter deliveries expected of the Standard units. Furthermore,

the Standards do not prevent the purchase of duplicates of units already installed for which drawings, patterns, etc., are at hand.

It is understood that the Report of the Joint Committee has been accepted by the Board of Directors of the A.I.E.E., and by the Executive Committee of Council of the A.S.M.E., subject to editorial correction. The accompanying table of sizes and conditions is taken from this report.

Discussion of Standards

Capability

In the early days of electric generation, most corliss or other engines were quite capable of carrying 25 per cent overload by lengthening the cutoff. The steam rate increased at this overload but peak demands were met. This practice was continued for competitive reasons with the early turbine-generators and 125 per cent of nominal rating was specified for many of these units with some advance in steam rate. Later, it became customary to meet the exigencies of the distribution system by a normal generator rating of a stated kilovolt-ampere capacity with 80 per cent power factor, but specifying that the turbine must be capable of driving the generator at its kva rating and 100 per cent power factor. This was equivalent to the older standard of 125 per cent of rated capacity in the turbine and was the basis for the condensing units in the 1938 Standards. Such maximum capacity of the turbine is known as its "capability." The footnote of the table defines "turbine capability."

Many purchasers of the older turbine-generators have systems which operate at power factors higher than 80 per cent. In many such instances the turbines could be operated continuously at loads exceeding their nominal rating and operators took pride in securing this excess capacity. However, the manufacturer had included the cost of this excess capacity in the price of the unit and operating company executives soon learned what excess capability could be expected of each turbine that was purchased.

The Joint Committee considered that a capability of 10 per cent above rating was sufficient to care for variations which occur by reason of geographic location of units and electrical and mechanical contingency factors in operation. Both the turbine rating and capability are expressed in the table as kilowatts output at the generator terminals.

Increased capacity can be obtained from an extraction turbine by shutting off the higher pressure extraction heaters. This increases the steam flow to the condenser, thereby increasing the output of the unit at the same throttle steam flow. But due to increased leaving losses and decreased final feedwater temperature, the heat rate of the unit is increased when a heater is shut off. This requires a greater fuel input to the steam generator with consequent increases in auxiliary power for forced- and induced-draft fans, coal pulverizers, etc.

PREFERRED STANDARDS FOR LARGE 3600-RPM 3-PHASE 60-CYCLE CONDENSING STEAM TURBINE-GENERATORS

	Air-Cooled Generator		Hydrogen-Cooled Generator Rated for 0.5 Psig Hydrogen Pressure			
Turbine rating, kw	11,500	15,000	20,000	30,000	40,000	60,000
Turbine capability, kw	12,650	16,500	22,000	33,000	44,000	66,000
Generator rating,						
kva	13,529	17,647	23,529	35,294	47,058	70,588
power factor	0.85	0.85	0.85	0.85	0.85	0.85
short-circuit ratio	0.8	0.8	0.8	0.8	0.8	0.8
Throttle pressure, psig	600	600	850	850	850 or 1250	850 or 1250
Throttle temperature, F	825	825	900	900	900 or 950	900 or 950
Number of extraction openings	4	4	4	5	5	5
Saturation temperature, F, at openings at turbine rating with all extraction openings in service: 1st	175	175	175	175	175	175
2d	235	235	235	235	235	235
3d	285	285	285	285	285	285
4th	350	350	350	350	350	350
5th	...	...	...	410	410	410
Exhaust pressure, in. Hg abs	1.5	1.5	1.5	1.5	1.5	1.5
			Hydrogen-Cooled Generator Operated at 15 Psig Hydrogen Pressure			
Generator capability at 0.85 power factor, kva	...	...	27,058	40,588	54,117	81,176

Notes:
1. A tolerance of plus or minus 10 F shall apply to above saturation temperatures. (Tolerances shall be unilateral so as not to reduce the spread in temperature between adjacent extraction openings.)
2. "Turbine capability" is guaranteed continuous output at generator terminals when the turbine is clean and operating under specified throttle steam pressure and temperature and exhaust pressure, with full extraction from all extraction openings.

Sizes

As is shown in the table, six standard unit ratings at 3600 rpm, from 11,500 kw to 60,000 kw, have been selected, with one or two standard values of throttle pressure and temperature for each rating. The 11,500-kw rating was chosen as the logical step above the largest of the N.E.M.A. units, namely, 7500 kw. This N.E.M.A. unit has a capability of 25 per cent over nominal rating, that is, 9375 kw. The capability of 12,650 kw for the 11,500-kw standard unit exceeds this N.E.M.A. unit's capability by 35 per cent. The capabilities of the several sizes in the table increase successively by 30, 33, 50, 33 and 50 per cent. This range of capacities is expected to satisfy the needs of most users. The 30,000- and 60,000-kw standard units are considered the largest economical capacities for single-flow exhaust and double-flow exhaust turbines with the longest last-row blades now in use at 3600 rpm.

Generators

The generator kilovolt-ampere rating was chosen at 85 per cent power factor at nominal load and generators will be designed with 0.8 short-circuit ratio. This power factor is considered an average of present system conditions. Additional capability is available in hydrogen-cooled generators when the hydrogen pressure is raised from the usual value of 0.5 psig to 15 psig, as indicated in the table. This capability may be utilized if extraction heaters are shut off at peak load or to take advantage of the overload capability of the turbine where power factor cannot be increased above 85 per cent.

Steam Conditions

Several changes from the values that were contained in the 1938 Standards were made in throttle steam pressures and temperatures to conform with average current practice. For instance, the 650 psig pressure on the two smaller machines was decreased to 600 psig. The steam temperature of 950 F has proved satisfactory on units operating at 1250 psig and is now recommended as standard.

An absolute exhaust pressure of 1.5 in. of mercury was selected for the Standard ratings. Lesser absolute exhaust pressures will increase the leaving losses of the unit although this may be more than offset by the increased heat drop. Greater absolute exhaust pressures, as in the South in summer, decrease leaving losses but also decrease heat drop.

Extraction Conditions

To cover these conditions a definite number of extraction openings will be provided on each unit with specified saturated steam temperatures at each opening when the turbine is operated at rating and with full extraction occurring at each opening.

The 1938 Standards recommended only three extraction points for turbines up to 25,000 kw rating and four points for turbines above this size. Since the object of turbine standardization was to expedite construction and decrease first cost, each turbine casing should be designed for the largest number of extraction points that may be required. The number of openings that would be used will depend upon the use or nonuse of economizers or upon the necessity for high thermal economy due to high fuel costs. A lesser number of openings than provided can be used by simply blanking off the unused openings.

The saturation temperatures at the extraction openings vary slightly from those in the earlier Standards. The temperatures in the new Standards give nearly equal temperature rises in the heaters. The footnote in the tabulation calls attention to permissible tolerances in these temperatures due to slight variations in turbine stage construction.

Effects of Turbine Standardization

Attention has already been directed to the expectation that delivery will be expedited by the adoption of these Standards. Expected performances in Btu per kilowatt-hour for these standard cycles can be computed and made available to design engineers. This will save time in preparing estimates. Standard layout drawings can also be furnished. Patterns will need no changes with each new order.

Since the Standards prescribe both throttle steam conditions and extraction temperatures, standard heat balances can be computed. From these, it may be possible to select and design standard extraction heaters, evaporators, deaerators, boiler feed pumps and such auxiliary apparatus as drainers, vent lines, etc. Standard condensers and condenser pumps may be possible although in individual cases average vacua may differ somewhat from 1.5 in. absolute and special condenser equipment may be justified. These standard equipments should be available at lower costs than is now the case with special designs.

A degree of standardization may also be achieved in steam generator design since capacities, pressures, steam and feedwater temperatures will be fixed. Steam generator standardization is a more difficult matter than with the equipment considered above for the reason that different fuels are burned in different furnaces, requiring modifications in design. However, since the cost of the steam generating section forms a considerable proportion of the total cost of a plant, no savings from possible standardization of this section should be overlooked.

Valves and fittings can, in a large measure, be standardized for each rating. Steam piping arrangement depends upon the relative location of turbine and steam generator and consideration may also be given to standardized locations.

Granted that all of the above standardizations may be achieved, a complete standard power plant design may be possible. This, however, presents some difficulties due to contingencies of location, water supply, electrical distribution and particularly the available fuels, fuel handling and storage.

Many anticipate that high costs of materials and labor after the War, combined with fixed electric rates and competitive conditions, will make power plant owners more dollar-conscious than heretofore. The new Standards should aid in reducing the cost of new stations and should therefore prove acceptable to both owners and designers.

Consumption of Fuel for Production of Electric Energy

Coal consumption by electric utility power plants was 6,490,371 tons in February 1945, according to the Federal Power Commission. This is a decrease of 927,322 tons from the January 1945 consumption, and a decrease of 250,649 tons or 3.7 per cent from the consumption for February 1944. Of this total 6,212,350 tons were bituminous coal and 278,021 tons were anthracite. This is a decrease of 12.7 per cent in the consumption of bituminous coal, and a decrease of 7.0 per cent in the consumption of anthracite when compared with the preceding month, which had three additional days.

The consumption of fuel oil during February 1945 totaled 1,701,084 barrels as compared with 2,148,428 barrels during January 1945 or a decrease of 20.8 per cent.

During February 1945 the consumption of gas decreased to 23,307,788 mcf from 24,818,393 mcf in January 1945 representing a drop of 6.1 per cent.

Stocks of Fuel

The total of coal stocks on hand at electric utility power plants on March 1, 1945, was 14,405,041 tons. This was a decrease of 9.4 per cent when compared with February 1, 1945, and a decrease of 4.8 per cent as compared with March 1, 1944. Of the total stocks, 12,916,181 tons were bituminous coal and 1,488,860 tons were anthracite. Bituminous coal decreased 10.2 per cent and anthracite decreased 2.8 per cent when compared with February 1, 1945.

In terms of days' supply, which is based on the rate of consumption for the month of February 1945, there were sufficient stocks of bituminous coal on hand March 1, 1945, to last 58 days and sufficient anthracite for 150 days' requirements. These may be compared with 61 and 159 days' supply, respectively, for February 1.

THE BRITISH GRID IN WAR TIME

Following is a digest of the reports of the Central Electricity Board for the years 1940–43 which have recently been released. They tell of the measures taken to meet the rapidly increasing war demands for power, despite material and labor shortages. Capacities, load factors and outage figures are given and some of the operating difficulties are cited. Plans for post-war expansion are included.

THE contribution of the Grid to the war effort in England is revealed in the annual reports of the Central Electricity Board for the years 1940 to 1943 which recently have been released for publication, following censorship relaxations.

In the early stages of the war the system of interconnection, as provided by the Grid, enabled important supplies of electricity to be made available for the rapidly expanding demands of munition plants and other factories; and later, when those demands exceeded the capacity of the generating stations in the areas in which they were located, the flexibility of the system, enhanced by wartime extensions brought into service, facilitated the transfer of the necessary power from the pooled generating resources in those areas in which demands had abated. While the Grid itself enjoyed comparative immunity from serious dislocation by war damage, it proved of great advantage in affording a valuable insurance against any locality being deprived of electricity through damage by enemy action to its generating stations.

Considerable expansion took place, during the four years, both in the Grid itself and in the generating stations serving it. Some 670 miles of lines were added to the transmission system, as well as numerous switching and transforming stations. At the end of 1943, the Grid comprised 5099 miles of transmission lines, 3585 of which operated at 132,000 volts and the remainder at 66,000 and lower voltages, and 344 substations with an aggregate transforming capacity of 13,058,750 kva. Five new generating stations were added, thus bringing the total of selected stations at the end of 1943 to 142 with an aggregate installed capacity of 10,984,656 kw.

There was a progressive increase throughout the period in the output of electricity from the public supply systems, except during the fuel economy campaign in the winter of 1942–43; and the total output, which was a little over 26,400,000,000 kwhr in 1939, rose to some 37,000,000,000 kwhr in 1943, an increase of over 40 per cent. This represented 98.65 per cent of the total for the entire country, excluding the north of Scotland.

The reports disclose in detail some of the difficulties which the Board encountered in carrying out the extension programs. These difficulties arose mainly from shortage of labor and materials, the attitude of the Government's production executives being that the necessary priorities could not be granted for plant extensions unless necessary to the war effort. As early as 1941, the Board, impressed with the danger of a national shortage of generating capacity in the years immediately following a return to peace conditions, urged upon the Government the seriousness of the position which was likely to arise if, for reasons of war policy, the necessary priorities were not granted. Again, in 1942, the Board put forward a substantial program of new plant construction for the autumn of 1945, but eventually the Minister of Production allowed only about one-third of that program.

During 1943, the Board felt it essential to make plans for meeting the situation which would arise if the war came to an end in the autumn of 1944 and put forward a program of new generating plants some of which would be required to be in service by the autumn of 1947 and the whole by the autumn of 1948. The greater part of that program was approved with the understanding that orders could be placed for the main items of equipment involved in the authorized projects, but that, pending the cessation of hostilities with Germany, manufacture should not be undertaken until further consent is given. In framing this program, the Board did not make provision for the immediate replacement of some 2,000,000 kw of obsolete equipment which would be over 20 years old by the winter of 1947. Instead, it decided that, with the interconnections provided by the Grid, no undue risk would be involved in deferring full replacement of such equipment until it was 25 years old.

Operation of the Grid was affected by the war in various ways. From the outbreak of hostilities it became necessary for the Board to depart substantially from its peacetime policy of concentrating generation in the most economical stations and to keep a larger amount of generating capacity than usual in constant readiness to secure, as far as possible, continuity of supply in an emergency. The black-out restrictions and the longer hours of working in the factories resulted in the demand for electricity being more constant throughout the day, and in consequence, the load factor on the Grid system, which was about 36 per cent in 1938, rose to some 50 per cent in 1942. Due to a higher maximum demand in 1943, there was a decline to about 48 per cent in the year. A further effect of the war on Grid operation, brought about by the black-out restrictions and the continuance of "summer-time" throughout the winter months, was a transference of the peak demand, which in pre-war days was normally in the evening and limited to about one hour per day during the fortnight immediately preceding Christmas, to a period extending with little variation throughout the morning during three or four winter months.

A number of factors increased the difficulties of operation. Among these were (1) the necessity to run, for long hours, units which would normally be used only for short peak periods; (2) reduced periods for maintenance; (3) shortage of labor for maintenance work; and (4) the inferior and variable quality of coal which resulted in a reduction of output and efficiency of the boilers. The combined effect was to reduce the average thermal efficiency of the stations operating under the

directions of the Board during 1941 and 1942 by some 3 per cent below that recorded in 1939. This was accompanied by a substantial increase in the quantity of coal consumed. During 1943, however, owing to improved war conditions and to new generating stations having been put into service, a saving of over 400,000 tons in coal consumption was effected over that which would have been consumed on the 1942 level of thermal efficiency, although the average thermal efficiency attained was still 1 per cent below the 1939 level.

Added to the difficulties of carrying out the necessary maintenance work, a progressive increase in breakdown of equipment brought about a serious reduction in the amount of plant capacity available for service. During the period of heavy demand in the winter of 1942–43, the aggregate capacity out of commission due to overhaul, breakdown and other causes averaged 1,250,000 kw and in the winter of 1943–44, 1,857,000 kw; these figures being, respectively, 13 per cent and 18.6 per cent of the aggregate output capacity of all the generating stations operating under the Board's direction. The prewar average outage from all causes was approximately 6 per cent.

The Board's annual accounts covering the first four years of the war show that the gross receipts from sales of energy rose from £37,899,128 in 1939 to £68,299,560 in 1943.

EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

Stationary Power Boilers

	1944		1943		1944		1943	
	Water Tube		Water Tube		Fire Tube		Fire Tube	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	36	226,537	11	64,189	24	31,701	16	18,888
Feb.	39	256,942	32	164,800	28	43,341	237	146,834
Mar.	47	229,121	31	147,937	44	53,893	16	24,293
Apr.	80	454,175	95	361,746	50	68,430	21	32,392
May	74	392,347	127	683,052	49	66,722	9	14,106
June	65	286,486	163	679,306	70	92,621	25	41,073
July	78	457,442	31	222,253	56	67,126	18	9,549
Aug.	112	441,222	51	311,448	52	69,832	30	38,797
Sept.	123	532,895	40	145,587	52	68,783	33	40,599
Oct.	119	603,687	103	301,574	65	79,289	26	34,542
Nov.	135	490,233	52	273,488	68	82,182	13	19,470
Dec.	56	367,755	87	1,035,005	55	78,820	27	53,312
Jan.–Dec. incl.	968	4,738,842	823	4,390,385	613	802,740	138	662,863

* Includes water wall heating surface.

Total steam generating capacity of water tube boilers sold in the period Jan. to Dec. (incl.), 1944, 55,032,000 lb per hr; in 1943, 183,327,000 lb per hr.

	1945		1944		1945		1944	
	Water Tube		Water Tube		Fire Tube		Fire Tube	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	105	656,593	36	226,537	50	60,710	24	31,701
Feb.	103	496,586	39	256,942	75	99,815	28	43,341
Jan.–Feb. incl.	208	1,153,179	75	483,479	125	160,525	52	75,042

* Includes water wall heating surface.

Total steam generating capacity of water tube boilers sold in the period Jan. and Feb. (incl.), 1945, 11,583,000 lb per hr; in 1944, 4,064,000 lb per hr.

Marine Boiler Sales

	1944		1943		1944		1943	
	Water Tube		Water Tube		Scotch		Scotch	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	49	273,879	597	2,185,483	—	——	1	1,080
Feb.	96	507,658	31	102,404	30	9,000	–	——
Mar.	70	226,166	156	430,841	38	9,700	1	2,565
Apr.	44	209,906	19	85,244	48	14,405	2	5,130
May	94	443,130	594	4,985,280	37	11,100	3	6,401
June	193	1,003,435	895	4,241,507	32	13,100	1	2,565
July	113	392,704	386	1,852,389	22	8,120	1	2,565
Aug.	182	811,978	729	3,320,329	26	11,983	4	7,730
Sept.	14	23,768	74	321,124	22	9,781	2	5,130
Oct.	52	67,560	39	166,373	36	16,085	2	5,130
Nov.	19	164,458	84	343,595	23	11,262	1	988
Dec.	60	283,878	66	309,682	12	7,540	2	1,976
Jan.–Dec. incl.	986	4,413,738	986	4,319,879	326	122,076	20	41,260

* Includes water wall heating surface.

Total steam generating capacity of water tube boilers sold in the period Jan. to Dec. (incl.) 1944, 55,032,000 lb per hr; in 1943, 183,327,000 lb per hr.

	1945		1944		1945		1944	
	Water Tube		Water Tube		Scotch		Scotch	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	363	1,542,274	49	273,879	6	1,073	—	——
Feb.	34	178,726	96	507,658	5	1,186	30	9,000
Jan.–Feb. incl.	397	1,721,000	145	781,537	11	2,259	30	9,000

* Includes water wall heating surface.

Total steam generating capacity of water tube boilers sold in the period Jan. and Feb. (incl.), 1945, 15,659,000 lb per hr; in 1944, 8,811,000 lb per hr.

†Mechanical Stoker Sales

	1944		1943		1944		1943	
	Water Tube		Water Tube		Fire Tube		Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.	35	13,982	131	46,948	149	20,961	457	31,623
Feb.	34	18,437	106	34,685	158	22,655	575	83,673
Mar.	56	20,128	114	48,367	150	22,884	571	77,729
Apr.	69	26,461	96	32,251	183	25,838	432	64,022
May	54	20,920	96	39,640	225	30,817	414	57,889
June	57	21,055	118	61,415	295	35,952	296	49,760
July	80	28,543	98	50,992	290	41,910	379	52,680
Aug.	115	35,077	68	31,377	359	48,612	446	62,732
Sept.	110	34,586	49	18,911	296	36,268	446	55,496
Oct.	90	29,926	159	53,382	328	44,262	391	54,477
Nov.	120	33,489	57	21,619	242	29,799	247	33,495
Dec.	103	34,626	60	62,853	277	35,764	204	25,712
Jan.–Dec. incl.	923	317,230	1,152	502,440	2,952	395,722	4,858	648,490

† Capacity over 300 lb of coal per hour.

	1945		1944		1945		1944	
	Water Tube		Water Tube		Fire Tube		Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.	43	19,423	35	13,982	185	24,899	149	20,961
Feb.	58	22,760	34	18,437	162	20,565	158	22,655
Jan.–Feb. incl.	101	42,183	69	32,419	347	45,464	307	43,616

† Capacity over 300 lb of coal per hour.

Causes and Prevention of Overheated Grates

Considering only stokers of the chain- or traveling-grate types, the burning or warping of links and keys usually occurs in the region where complete ignition penetration of the fuel bed takes place. How to avoid overheating of the metal by proper operating procedure and how to measure the temperature in this location are explained and illustrated.

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Combustion Engineering Company

BURNING or warping of the grate surfaces of stokers is responsible for high stoker maintenance, a reduction in efficiency of operation, and unnecessary outage of steam-generating units. While this applies to all types of stokers, the present discussion deals only with traveling and chain grates. It reviews some of the conditions that lead to overheated grates; shows how to determine the temperature to which they are subjected; and offers suggestions for the prevention of overheating.

Basically, with any type of stoker or grate, the two principal factors which are depended upon for the prevention of burning are (1) air sweeping the under surfaces of the grate before coming into contact with the fuel where it sustains combustion, and (2) ash which accumulates on the grate and protects the metal from the high temperature of the incandescent fuel. It may be well to mention that the individual units of the grate surface of a traveling grate stoker are referred to as keys, and those of a chain grate stoker as links.

With a traveling or a chain grate stoker, ignition takes place on the surface of the fuel bed and penetrates gradually downward until the entire depth is ignited. From the time the fuel enters the furnace until complete penetration of the fuel bed occurs, the keys or links are well protected against overheating by a layer of green fuel. The temperature of the keys or links, up to the point of complete penetration of ignition, even if preheated air is employed, usually does not exceed 250 F, and generally ranges between 200 and 250 F.

When ignition of the full depth of the fuel bed occurs, the temperature of the keys or links rises sharply, usually to about 400 to 800 F, depending upon the ash content of the fuel, the rate of combustion, and the cross-sectional design of the key or link. Immediately following complete penetration of ignition, and before any perceptible amount of ash has been deposited on the grate, the keys or links are exposed to the maximum danger of burning. The maximum rate of burning often occurs at this location in the fuel bed; yet, despite the absence of an accumulation of ash on the grate, the metal need not reach a temperature high enough to cause burning or warping. But, if for any reason the air supply at that location is reduced too much, keys or links are sure to be overheated.

As an illustration, if a very light load is being carried on a stoker, and air for combustion is admitted along too much of the length of the fuel bed (in other words, if too many stoker compartments or zones are in use), the required amount of steam will be generated by using a comparatively small quantity of air in one compartment. In that case it is probable that there will not be sufficient air passing between the keys or links where ignition

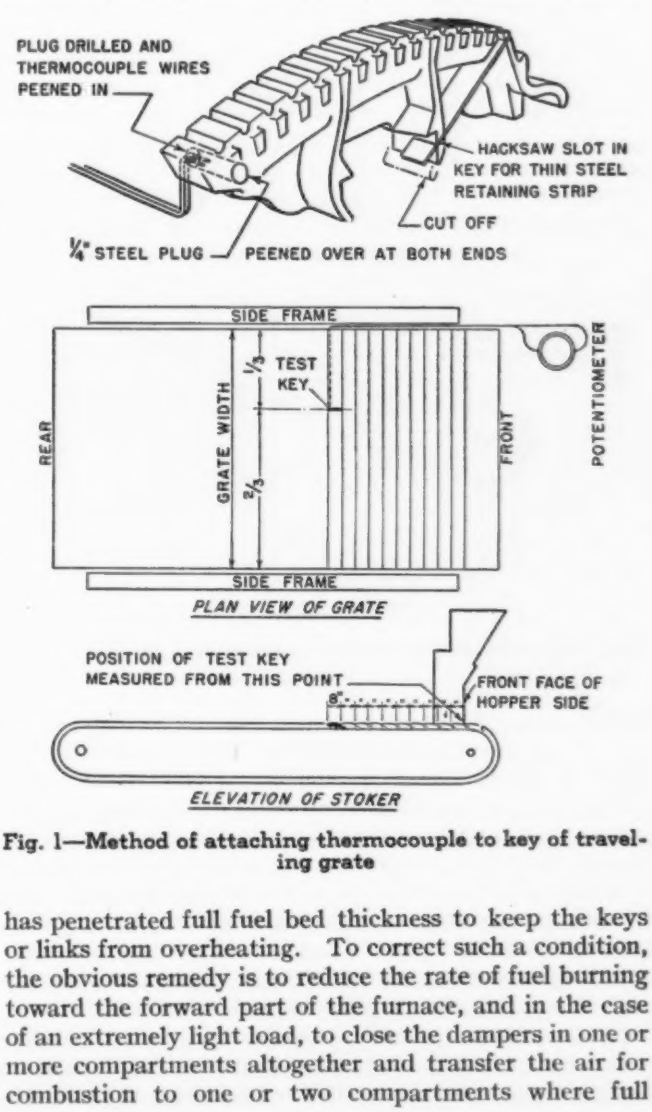


Fig. 1—Method of attaching thermocouple to key of traveling grate

has penetrated full fuel bed thickness to keep the keys or links from overheating. To correct such a condition, the obvious remedy is to reduce the rate of fuel burning toward the forward part of the furnace, and in the case of an extremely light load, to close the dampers in one or more compartments altogether and transfer the air for combustion to one or two compartments where full

depth of ignition has taken place. In doing so, there will be enough air passing through the grate to protect it against burning. This suggestion applies in the case of stokers operated by combustion control systems as well as to hand-operated stokers.

What has been referred to as the point, or location where ignition penetrates the entire fuel bed, cannot be determined simply by looking at a fire. Studies of grate temperatures, however, furnish a guide as to the location of this hot zone. It is frequently about $1^1/_2$ to 2 compartments from the extreme end of the fire, where the fuel is burning most actively. A good rule to follow then is to make sure that air pressure in the compartments under the brightest part of the fire should never for an extended period be reduced below about one-half the pressure normally used in those compartments. For example, if the normal air pressure in the most active compartment of a stoker burning No. 3 buckwheat is, say, $1^1/_4$ in., it is not advisable to reduce the air pressure in that compartment to less than about $^3/_4$ in. for any appreciable length of time. Or if the normal air pressure in the most active compartment of a stoker burning bituminous coal is about $^3/_4$ in., the grate will likely overheat if the air pressure in that compartment is reduced from $^3/_4$ in. to about 0.3 or 0.4 in. and allowed to remain there for several minutes.

Fuel Bed Should Not Be Disturbed

Reference has been made to ash deposited on the grate when the fuel is burned, as a protection against overheating of the keys or links of traveling grate and chain grate stokers. In normal operation the fuel bed on a stoker of either of these types should never have to be disturbed with a firing tool. If proper fire thickness, grate speed and air pressures are maintained, the fire will

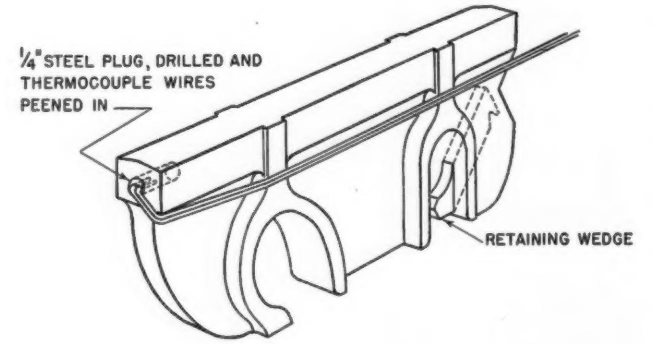


Fig. 2—Attachment of thermocouple to link of chain grate

usually burn out evenly across the stoker, unless there is uneven air spacing in the grate, accumulation of clinkers along the side walls, air leakages, especially at the sides of the furnace, segregation of sizing of the fuel on the grate, etc. If a fire persists in burning out unevenly, the cause should be ascertained and the difficulty corrected. Working a fuel bed with a firing tool will break up the layer of ash and allow incandescent fuel to come in direct contact with the grate. Instances have been found where such disturbance of the fuel bed has produced grate temperatures as high as 1800 F.

Grate surfaces may be burned by improper or careless preparation of a fuel bed for banking. An operator usually knows long enough in advance of the time that a fire has to be banked to permit burning the fuel bed down properly, so as to avoid overhauling the grate. A fire should not be allowed to simply "die out" or to burn down under low air pressure. If, for example, one-fourth or one-third of the length of a fuel bed is to be held as a bank, the remaining three-fourths or two-thirds of the length of the fire should be burned to ash, and under air supply at least equal to that which would be used in normal operation.

Measuring the temperature of stoker keys or links during operation or banking of a fire is a simple matter if a potentiometer and thermocouple wire are available. Insulated iron and constantan wires, either single or duplex,

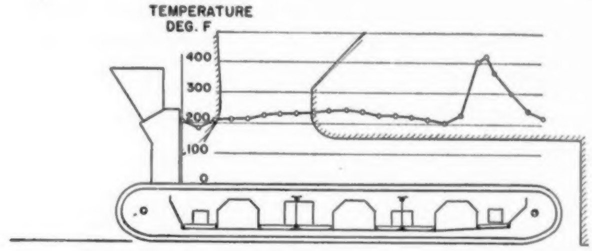


Fig. 3—Temperature corresponding to good operation

of about 20 gage are most convenient for this purpose. The insulation should be such as to withstand temperatures up to about 2000 F.

Method of Applying Thermocouples

Fig. 1 shows the method of applying a thermocouple to a key of a traveling grate stoker, and attaching the key to the stoker during operation. The forward or leading end of the key is drilled and a $^1/_4$ in. steel plug is inserted and peened in to make good contact with the cast-iron key. The plug is then drilled to receive the thermocouple wires, which are carefully peened in place. Since it is necessary to put the key containing the thermocouple on the grate bar without stopping the stoker, the rear lug which holds the key on the bar is cut off. A slot can be made with a hack saw, and a thin metal strip inserted in the slot as illustrated, to keep the key from falling off the bar as it moves around the end of the stoker. By doing so, the thermocouple key can be removed and a regular key substituted if desired when the stoker has made a complete revolution.

As the thermocouple key is fastened on the bar, the wires must not be allowed to extend upward to the top of the grate; otherwise they will burn. Instead, the wires must be pushed downward between adjacent keys. There are some types of stokers that have grate bars without sealing plates at their ends, but with a space of perhaps $^1/_2$ in. between the bar ends and the side frames. With such stokers, the wires should be carried underneath the leading ends of the keys, to one end of the bar, where there is ample space for the wires to travel with the bar toward the rear of the furnace. If there is no space at the end of the bar, then adjacent keys must be separated (by use of a screwdriver or other convenient tool) and the wires pushed downward about $^1/_2$ in. below the top surface of the keys. This will have to be done as each succeeding bar comes along. It is well to drive wooden pegs between the keys after the wires have been pushed into position, to keep them in place.

A base line should be provided at the front of the stoker, and when the leading end of the thermocouple key passes the base line, its bar can be numbered 1, and the succeeding bars numbered in order as they pass the base line. In that way, since the spacing of the bars is known, the exact location of the thermocouple is known at all times.

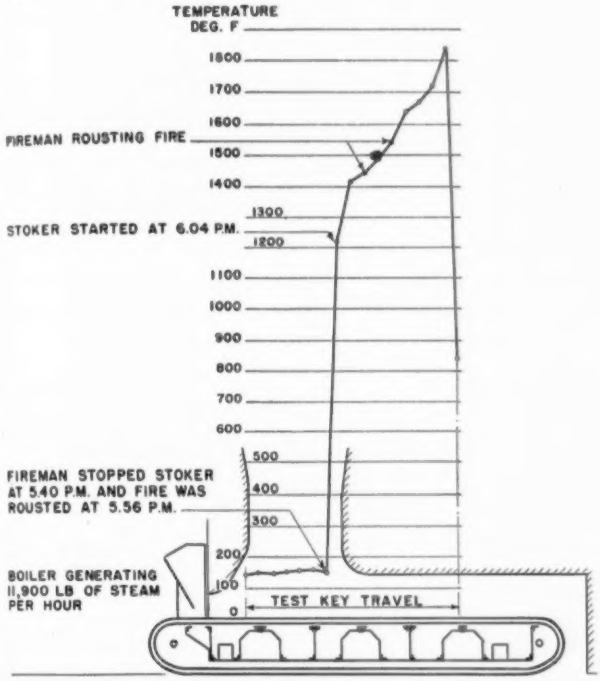


Fig. 4—Temperature of keys with incorrect stoker speed and air supply, and raking of fuel bed

Fig. 2 shows a means of attaching the thermocouple to a link of a chain grate stoker. The end of a link is drilled and a steel plug inserted, and the thermocouple wires peened in place, as in the case of the traveling grate key. The links must be separated and the wires pushed down below the surface of the grate, as each succeeding pair of links moves along.

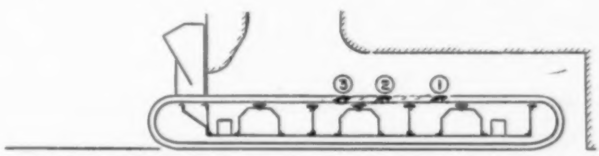
When the final temperature observation of any study has been made, the wires can be cut at the grate. The used wires can be removed from the stoker when it has made a full revolution.

Temperatures with Proper and Improper Operation

Representative temperatures of the keys of a traveling grate stoker under good operating conditions is shown in Fig. 3. The fuel burned in this case was No. 3 buckwheat anthracite, and the air distribution to the several stoker compartments was such that no excessive temperature occurred at any part of the stoker's travel. The temperature went up to a low and entirely safe maximum when the ignition had penetrated the full depth of the fuel bed, then dropped as the coal burned out and ash accumulated on the grate. Experience indicates that where the grate temperatures follow a pattern similar to that shown in Fig. 3, the keys do not burn, even when a maximum temperature of 800 to 900 F exists for a very short time.

An example of improper stoker operation is illustrated by the temperature diagram shown in Fig. 4. The load on the unit was about 80 per cent of the rated capacity of the boiler. A combustion control system was in use, and the relation between coal feed and air supply was such that the fire was generally too long. Instead of adjusting the coal feed, as should have been done, the operator stopped the stoker occasionally, and then in order to hasten the burning out of the fuel bed, or to correct an irregular end of fire, he raked the fuel bed with a firing tool. The result was that the grate was at a temperature of over 1400 F. for about twenty minutes. If the correct stoker speed had been maintained, and air for combustion had been applied properly, the keys would not have reached a dangerous temperature. It is evident that improper operation of this kind was the general practice in this plant, since practically all of the keys on the stoker are badly warped and burned.

Fig. 5 shows the temperature of three keys at different locations on a traveling grate stoker while the fuel bed was being prepared for banking. The stoker was stopped and the fire was burned out under too low air pressure.



THIS SKETCH INDICATES THE POSITION OF THE TEST KEYS ①, ② AND ③ DURING THE BANKING PERIOD WHEN THE STOKER WAS STOPPED AT 1.37 P.M.

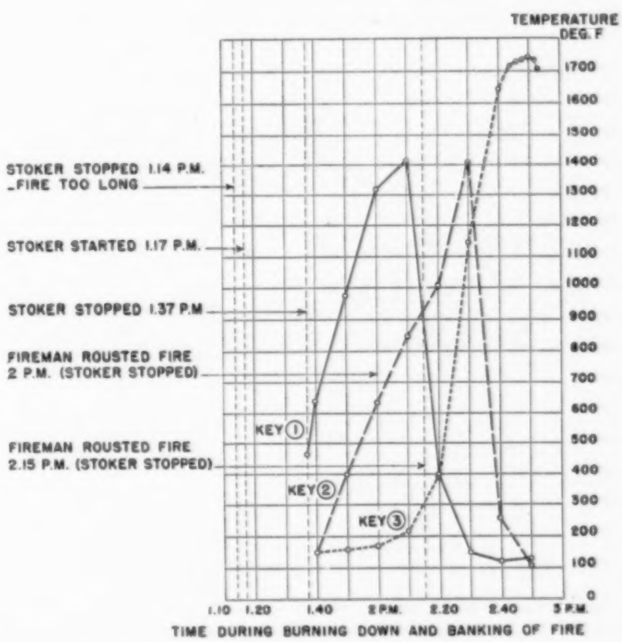


Fig. 5—Excessive temperature due to improper banking procedure

Here again, in order to hasten the burning, the operator raked the fuel bed with a firing tool. One key reached a temperature of about 1740 F and all of the keys were hot enough to cause them to be burned.

The results of a study of overheating of the links of a chain grate stoker are shown in Figs. 6 and 7. The stoker was operated at all times by careful, intelligent men. The fire was not too long and the air distribution in the stoker compartments was watched carefully. When the temperature study shown in Fig. 6 was made,

the fuel bed was burned to ash near the middle of the length of the stoker. The temperature of the thermocouple link reached a safe maximum where ignition penetrated the fuel bed, then gradually lowered as the stoker link moved toward the rear of the furnace. But despite the fact that the rear portion of the stoker was covered with ash the thermocouple link was again heated to a temperature actually higher than was observed at the location of ignition penetration.

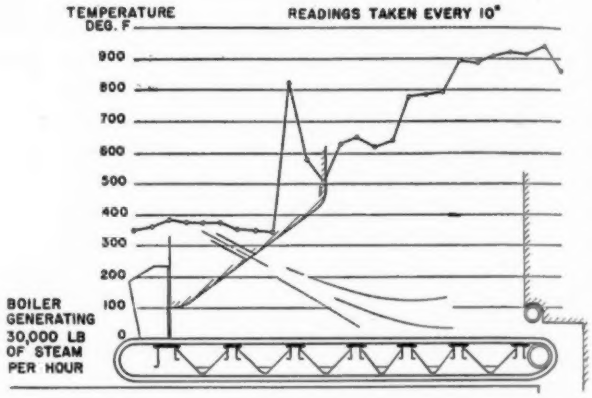


Fig. 6—High temperature due to improperly applied overfire air, but with otherwise good operation

It will be noted that overfire air jets were installed in the sloping arch at the front of the furnace, and directed downward toward the rear portion of the grate. One of the plant engineers called attention to the fact that the jets appeared to cause hot gases to be carried downward to the grate. The overfire air fan was shut down and a second thermocouple link was carried through the furnace. Fig. 7 shows the temperature of that link while the unit was operated at the same output as when the observations shown in Fig. 6 were made. It was evident that improperly located air jets were causing the

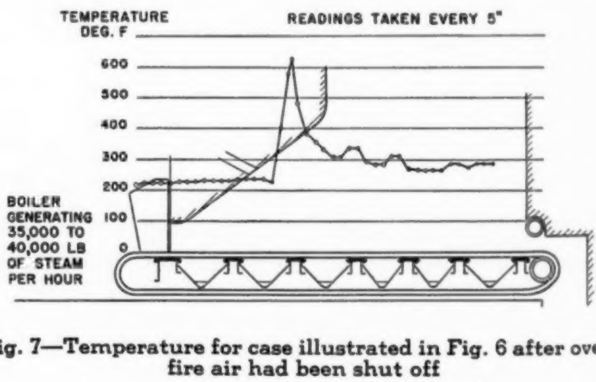


Fig. 7—Temperature for case illustrated in Fig. 6 after overfire air had been shut off

grate to be overheated. While the temperature of the links was not high enough to cause serious burning when this study was made, it was thought that under certain conditions of load and overfire air supply, grate burning could occur; hence the location of the jets was changed.

The foregoing examples are a few of many studies which have been made to solve problems that occasionally arise in the operation of chain grate and traveling grate stokers. Most common among these problems, of course, is the burning of the grate surfaces. The method used is simple and the results are reliable.

POWER FOR CEMENT PLANTS IN CHINA

By PAUL H. CHANG, Ch. Engineer

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This account of the oldest and largest cement company in China is representative of the development of that industry and its power practices. Handicapped by limited facilities and enemy attack, operation has involved many difficulties.

THE portland cement industry in China started about the beginning of the present century with the installation of small ball-and-tube mills and shaft kilns at Tangshan, approximately 80 miles northeast of Tientsin. For several years this was the only cement plant in China and it preceded the British undertaking at Green Island. Later, in 1904, this small plant at Tangshan developed into the Chee Hsin Cement Company and was expanded by the installation of two 6-ft 10-in. × 100-ft rotary kilns and ball-and-tube mills for raw and finished grinding. The power was furnished by a 750-hp compound engine supplied with steam at 150 psi by three 1700-sq ft boilers. With this set-up an annual output of 300,000 bbl of cement was attained.

Expansion of Facilities Begun

At about this time construction was begun on the railroad between Tientsin and Nanking and there arose a considerable demand for cement to be used for bridges and stations. Accordingly, the plant was further expanded in 1910 by the addition of two larger kilns and a 1300-hp engine, to supply which four more boilers were added. This engine was coupled to a 1250-kva, 3-phase, 2300-volt, 50-cycle generator and the output of cement was stepped up to 700,000 bbl per year.

Following World War I, in 1918, the plant was expanded for a third time by the addition of two 9 × 195-ft kilns, the grinding of raw material and clinker, as before, being performed by ball-and-tube mills. A new power plant was installed, consisting of a 6000-kva, 3-phase, 2300-volt, 25-cycle turbine-generator and six 2680-sq ft boilers supplying steam at 200 psi. The old boilers and steam engines were held in reserve.

Because of the high temperature of the gases leaving the kilns two waste-heat boilers of 4300 sq ft each and 200 psi pressure were installed in 1920, and this utilization of waste heat effected a reduction in the unit cost of producing the cement. The output at this time was stepped up to 1,500,000 bbl per year.

A few years later, in 1928, the demand for power further increased and, taking advantage of an opportunity to supply a nearby cotton mill and electricity for lighting the city of Tangshan, two more boilers and a 10,000-kva turbine-generator were added.

Meanwhile, the Company had acquired control of another cement plant, located at Tayeh in the Yangtze Valley about 90 miles below Hankow, which had a capacity of some 400,000 bbl a year; and in 1936 it erected a third plant of 1,200,000 bbl output near Nanking. This made an aggregate capacity in the three plants of over three million barrels a year, all of which are now in Japanese occupied territory and are likely to be destroyed at the time of enemy evacuation.

Difficulties Encountered in Moving Equipment

However, shortly before the Japanese reached Hankow, the Company, with the assistance of the Government, succeeded in moving a portion of the machinery from the Tayeh Plant to a new location at Western Hunan in Free China, some three hundred miles distant. The equipment that was moved consisted of four hand-fired sectional-header boilers, one 750-hp compound non-condensing engine and cement-making equipment capable of producing about 600 bbl per year.

Removal of this equipment to its new location was an arduous task. Although the distance was only 300 miles, seven months were required in transit and six months for erection. Since railroad transportation was not available, all pieces of equipment had to be sent up the river on sailing vessels, the largest of which had a capacity of 50 tons. Some pieces of the disassembled equipment weighed as much as 10 tons. But this was not all; further on, all pieces had to be reloaded on to smaller shallow-draft craft in order to traverse the small less navigable streams before reaching the destination, and these craft frequently ran aground. Everything had to be handled by manpower and approximately 200 men were required for the job. It is not surprising that some of the equipment was damaged in transit.

Latest reports, however, indicate that this installation is still free from enemy control, although it has been bombed many times and on one occasion a direct hit caused such damage to the power plant that repairs required nearly six months, owing to the limited facilities available.

By removal of the equipment from Tayeh to Western Hunan and because of Japanese domination of the other plants, the relation with the Chee Hsin Cement Company in the North was broken. Hence, from 1938 to 1943 this plant carried the name of Hwa Chung Cement Company and from 1943 to date it has been amalgamated with the Kunming Cement Company in Yinnan Province to form a new company called the Hwa Hsin Cement Company which is now the largest in Free China and is engaged in planning new plants for post-war China. Among these is a plant having two large kilns each 425 ft long which will require an 8000-kw power plant.

BOILER OPERATION AT HIGH ALTITUDE

The following was instigated by a letter recently received in which the writer offered a theoretical analysis of the problem to substantiate his contentions, based on personal observations. This is reviewed together with comments on certain practical aspects, inasmuch as it is an interesting subject concerning which little has appeared in print.

THE effect of altitude on power output has long been recognized for certain types of installations that are to operate in locations considerably above sea level. For instance, a diesel engine, without supercharging, will ordinarily develop only about two-thirds its rated power when located at an elevation of 10,000 ft, or about 80 per cent at 5000 ft; and altitude is known to affect both the capacity and the performance of a non-condensing steam engine. Likewise, correction factors for altitude are always applied when figuring the capacity of fans and the size of stacks that are designed to operate under such conditions.

Density of the atmosphere varies inversely as the barometric pressure. At sea level atmospheric pressure is 14.7 psi; at 5000 ft it is 12.1 psi; and at 10,000 ft it is 10 psi. That is, generally speaking, the pressure decreases approximately $^1/_2$ psi for each thousand feet elevation above sea level, within the range usually encountered in power plant practice. Fan ratings are normally based on the average weight of air between sea level and 500 ft and for operation at higher elevations the capacity and horsepower must be multiplied by appropriate factors.

Since stack draft is proportional to barometric pressure, increased height is necessary at high altitudes and the diameter must also be increased to compensate for the added frictional losses produced by the greater height and to handle the greater volume of gas. However, it is not customary to deduct stack draft from the required static pressure when selecting a fan.

Theoretically, at least, the effect of altitude may be expected to extend further than the fans and stack and have some bearing upon both the stoker and the furnace. There have been instances where reduced normal output at high altitude has been attributed to failure to give full consideration to this fact. It has been offered as an explanation of why similar units, located at widely different elevations, behave differently, even with the same fuel.

One may consider, for example, a stoker of the chain- or traveling-grate type, as frequently employed to burn the fuels which are available to the higher altitude sections of the country. The grates of such a stoker are designed with openings large enough to permit passage of the proper amount of air for combustion at a velocity that will not tend to disturb the fuel bed unduly, so as not to result in excessive carryover of fines, and at the same time small enough to aid in the distribution of air through the entire fuel bed and to avoid excessive siftings into the ashpit. This percentage is usually determined for different fuels from experience under approximately sea-level conditions, and permits of considerable latitude in fuel-burning rates.

Remembering that *oxygen is burned by the pound but handled by the cubic foot,* let it be assumed by a stretch of imagination that the whole unit is elevated to 10,000 ft. It would still be required to burn the same amount of fuel with the same weight of air to produce the same output of steam, but the density of the air at this elevation is only 0.7384 of what it is at sea level. Therefore, for every cubic foot of air passed through the grates at sea level, 1.35 cu ft are required at 10,000 ft. This would require greater pressure under the grates and result in higher velocity through them and through the fuel bed. Hence, the fuel burning rate must be reduced proportionately if excessive carryover of fines is to be avoided. For obvious reasons, it may not be desirable to increase the size of openings in the grate to permit passage of this greater volume of air, but the objective can be attained by increasing the total grate area.

The same reasoning would apply to hand-fired grates, although with spreader firing the openings through the grate are purposely kept small to provide the desired resistance for air distribution.

Effect on Furnace

While some difference of opinion may exist as to the furnace, which is complicated by other factors, it is apparent that under the assumed conditions of altitude and regardless of temperature, the gases would have proportionately less density than a unit operating at sea level. With both the air and the gases that are distilled from the fuel bed at a lower density, an atom of gas must travel further to combine with its required amount of oxygen. This means greater flame length and consequently a longer time for combustion to be completed; which, in turn, would indicate a greater furnace volume to accommodate the larger volume of the products of combustion.

Thus one can picture a unit designed for sea-level conditions with the stoker and furnace stretched in inverse proportion to the density of air at the intended altitude, if comparable performance is to be attained.

The effect of altitude is not so marked as concerns the boiler proper. With the stoker and furnace enlarged to accommodate the increased volume of air and gas, it is true that the velocity through the boiler passes would be higher and the draft loss greater; but this would be partly offset by the fact that the heat transfer rate would be increased by the greater mass flow. However, the

gain in reproportioning the boiler would likely be too small to justify doing so.

So much for the theoretical aspects of the problem. Practically, there are other factors to be considered, some of which tend to compensate for the effects of altitude. For instance, although higher velocity through the grate will tend to lift particles from the fuel bed, lower density of the furnace gases, as indicated for higher altitude, would tend to cause these particles to fall more readily and thus at least partly offset the effect of higher velocity. Again, the extent of water cooling employed would have bearing upon the average gas temperature within the furnace, and, in turn, upon the gas density in the furnace.

All things considered, it would seem that aside from the fans and stack, and to some extent the furnace volume, the influence of altitude is less than might be expected from strictly theoretical considerations. Most units are designed with certain tolerances and for the comparatively few installations intended to operate at altitudes of 5000 ft or over, lower fuel burning rates can generally be employed without altering the air passages through the grate. In this connection there is a growing preference for considering heat release per square foot of grate rather than the long used pounds of coal per square foot.

In the final analysis, each case must be considered with reference to the particular factors involved and generalization should be avoided.

New Method of Measuring Fluid Flow Applicable to Heat Transfer Studies

This method of measuring fluid flow, by means of a magnetic field, was advanced by Alexander Kolin, of Columbia University, at the last A.S.M.E. Annual Meeting as applicable to studies of heat transfer from liquids to metals. A brief abstract of the paper follows.

THE problem of evaluating heat transfer between a solid wall and a moving fluid requires, in addition to the thermal data, a knowledge of the velocity distribution of the fluid in the vicinity of the wall. The following method makes such a study of the velocity distribution possible. Although, theoretically, the method could be used on any fluid, its range in studies made so far has been limited to water, electrolytic solutions and liquid metals.

The principle underlying the method herein described is that of electromagnetic induction. When a fluid moves through a constant magnetic field of intensity H a potential gradient E is induced in the fluid which, at a point where the local velocity of flow is v, is given by the expression:

$$E = (\mu/c)H, v$$

If the magnetic field is known, the determination of E at any point will enable one to evaluate the instantaneous value of the local velocity v. Fig. 1 presents a clear idea of the experimental arrangement by showing its stepwise evolution from Faraday's unipolar induction machine.

Fig. 1-A shows the original unipolar inductor. The emf induced in the part of the metal disk that moves between the magnetic poles is picked up and conveyed to the measuring device by the indicated sliding contacts. In Fig. 1-B the disk is replaced by a straight metal belt in which an emf is induced at right angles to its direction of motion and to the lines of force of the homogeneous magnetic field. Since this induced emf is proportional to the instantaneous velocity of the moving belt one can obtain a measure of the belt velocity and its fluctuations by recording the induced emf.

The next step, shown in Fig. 1-C, consists of replacing the metal belt by an electrolytic conductor flowing through a pipe made of electrically nonconducting material. The voltage induced in the moving liquid is picked up by electrodes which are introduced through the wall of the conduit to make contact with the electrolyte. The meter readings prove to be proportional to the average velocity of flow and follow rapid variations of flow without distortion if an appropriate oscilloscope is used as an indicator.

Now imagine the pickup electrodes of Fig. 1-C to be pushed into the conduit until they are separated by only a small gap as shown in Fig. 1-D. The electrodes are assumed to be thin enough so as to cause only a negligible disturbance in the local flow and insulated except for the tips. Under such conditions, the microvoltmeter reading will be proportional to the axial velocity component of the liquid between the electrodes, thus enabling one to obtain a time record of the variations of the local velocity of flow.

In order to be able to study the velocity distribution in space, the arrangement of electrodes can be altered as shown in Fig. 1-E. Two parallel fine wires which are insulated except for the tips are mounted on a holder which can be moved up and down by suitable means. In this manner, the velocity distribution in the vertical plane along a line traced by the wire tips can be obtained. In the figure the wires (diameter of the bar wire 4.10^{-3} in.) and the holder are shown on a greatly exaggerated scale in comparison to the pipe. The gap between the wires in most of the studies ranged from 4.10^{-3} in. to 15.10^{-3} in.

It is desirable to shield the tips of the electrodes from induced currents by thin sheets of mica. The voltage induced in the moving liquid between the tips of the exploring electrodes is picked up and amplified. An oscilloscope or a milliammeter may be used in the amplifier out-

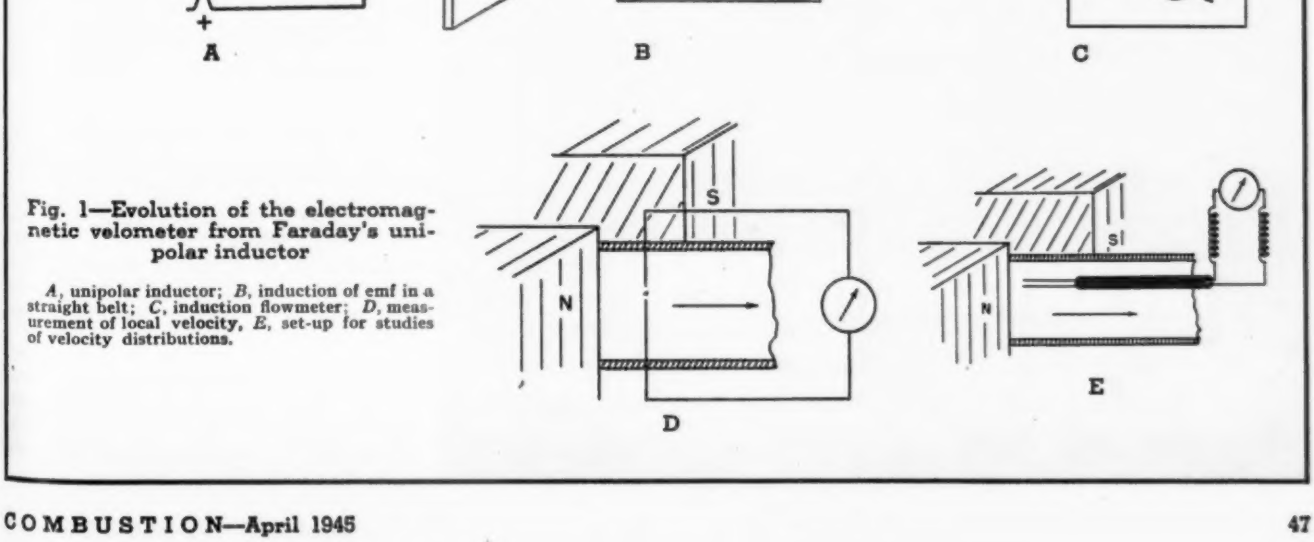


Fig. 1—Evolution of the electromagnetic velometer from Faraday's unipolar inductor

A, unipolar inductor; *B*, induction of emf in a straight belt; *C*, induction flowmeter; *D*, measurement of local velocity, *E*, set-up for studies of velocity distributions.

put to measure the rate of flow. To avoid difficulties due to polarization of the electrodes, and to facilitate the problem of amplification, an alternating magnetic field is used rather than a constant one. (For details of the electronic circuit, see A. Kolin, *Jour. of Applied Physics*, 15, 150–164 (1944).

Fig. 2 shows a series of velocity distributions obtained by means of this method

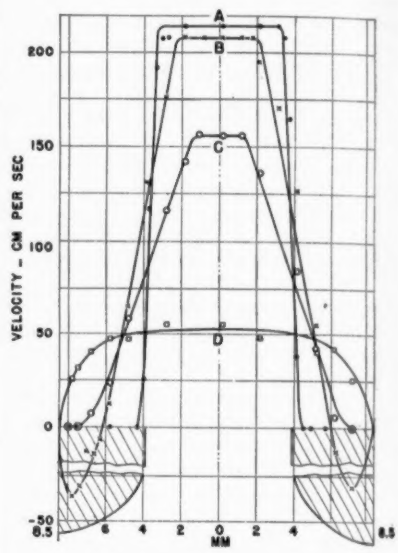


Fig. 2—Distribution of velocities at different distances below the nozzle

behind a nozzle at different distances from the latter.

In many instances the use of an external magnetic field may prove impractical. In such cases, a self-contained unit consisting of a miniature magnet with attached electrodes will prove desirable.

Personals

J. H. Walker, for a number of years assistant to the general manager and superintendent of central heating of The Detroit Edison Company has been elected a vice president. His connection with the Company dates back to 1912.

Ronald B. Smith, for several years past manager of engineering and development with the Elliott Company, has been elected vice president in charge of engineering for the company.

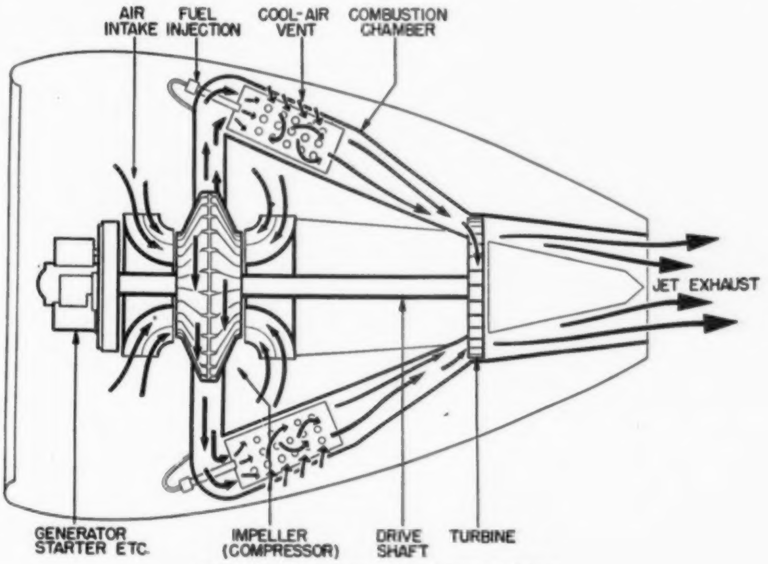
Charles C. Cheyney has recently been promoted to the position of sales manager of the Buffalo Forge Company.

Samuel J. Gates, Parker A. Moe and **Robert H. Weiss** have recently formed a partnership to engage in the practice of engineering, both industrial and power. They are located at 611 North Broadway, Milwaukee, Wis.

G. W. Van Derzee has been advanced from vice president and general manager of the Wisconsin Electric Power Company to president, succeeding S. B. Way who becomes chairman of the board.

Jet Propulsion

Although foreign to the stationary power plant field, many readers may have a general interest in jet propulsion which is now being employed to drive some of our new fighter planes at lightning-like speed. An idea of the principle involved and the arrangement can be gained from the accompanying simple sketch provided by the General Electric Company, which has pioneered in the development of this form of propulsion.



Simple diagram of jet propulsion.

Cold air, often many degrees below zero, is drawn into the compressor impeller, which is mounted on the same shaft as the turbine; and when compressed, this air is forced into the combustion chamber. Fuel, such as kerosene, is injected into the combustion chamber and ignited. This increases both the pressure and temperature of the gases which pass at high velocity to the turbine, the exhaust from which blasts over the exhaust cone and forms a high velocity jet. The reactive force of this jet drives the plane forward.

This form of propulsion has approximately one-tenth as many moving parts as does the ordinary reciprocating engine and maintenance is said to be very much simpler, an overhaul requiring only about one-fifth the time of the latter and less experience. Moreover, starting time is saved as the jet engine does not have to be warmed up.

ECPD to Advise Veterans on Engineering Opportunties

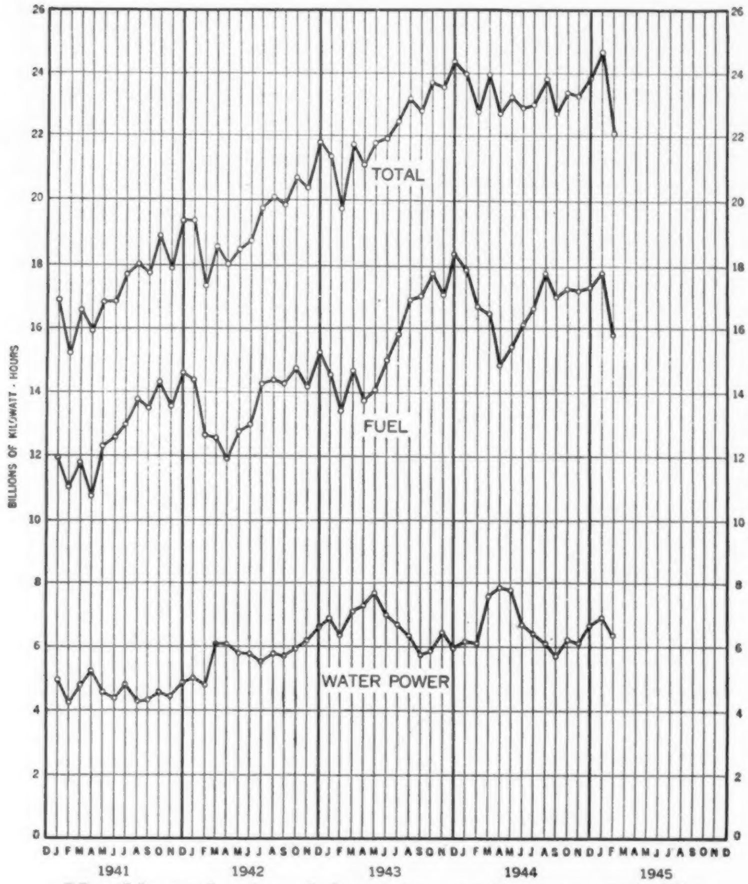
Vocational guidance aid to returning veterans who may look to engineering as a peacetime career and announcement of a plan for accrediting educational programs of the technical institute type are among the current activities noted in the Twelfth Annual Report of the Engineers' Council for Professional Development which was recently issued.

According to the report of the Committee on Student Selection and Guidance, "to serve these veterans adequately will require all the facilities at our command and will involve a considerable expansion of the subcommittee structure.... Veterans are gravitating naturally to facilities existent in their own localities. . . . Guidance, particularly of an informational character, should be made available to high-school principals and guidance officers. Informational material should be given concerning the profession, the requirements and responsibilities, colleges and Veterans Administration centers where engineering tests are given, and a list of local subcommittees of this committee. . . . A pilot survey of some two hundred schools in New York State and several in Canada reveals that these schools need and want this information. The fact that there are 25,000 high schools in the United States and 2000 in Canada gives an idea of the scope of the problem."

The measurement and guidance project of the committee which is being carried on under the direction of the Carnegie Foundation for the Advancement of Teaching is directed to the development of a battery of tests to aid the proper selection of students for engineering. During the first year of operation of the project eleven colleges of engineering cooperated in the work. Fifteen institutions in the United States and Canada have evidenced interest, and their inclusion in the projects awaits official sanction of the Advisory Committee. It is planned to extend the services offered by the project, as the Carnegie Foundation feels that the tests are now sufficiently developed to warrant a considerably wider application.

Accreditation of the curricula of engineering colleges in the United States which has been the major activity of the Committee on Engineering Schools for many years, was held to a minimum last year because the committee believed that engineering colleges cannot be fairly judged while operating under war conditions.

The Subcommittee on Technical Institutes completed an inclusive study of the present status of education of the technical-institute type in April, 1944.



Monthly production of electricity over four-year period by utilities and industrials, according to Federal Power Commission

To Coordinate Drafting Standards

At the request of the War Production Board the American Standards Association is starting to develop a series of American War Standards for drawing and drafting-room practice that will correlate the practices of the Army and Navy with those of industry.

ASA has long had a regular committee on drawing and drafting-room practice working under the joint technical leadership of the American Society of Mechanical Engineers and the Society for the Promotion of Engineering Education. Standards developed by this committee have laid down the simple basic elements of the subject. This new work proposes to carry the subject further.

The present existing diversity of drafting practices between the various branches of the Armed Forces and industry, together with its attendant waste and confusion and delays in providing the drawings needed for war equipment, has long been recognized by the Services. In accordance with a joint directive of the Secretaries of War and Navy to their departments the Services are setting up committees within their respective organizations to bring together the practices in the various branches of the Services and through the ASA to correlate these practices. The part of the ASA in this program will be in coordinating industry practices with those of the Services, making it possible for a single group of standards to serve both.

At present, a prime contractor having contracts with several government agencies has to spend considerable effort on the one minor item of seeing to it that each of his subcontractors and each division of his own company understand precisely what drafting practices are to be used on each job. While this represents only an exceedingly small part of the waste of manpower resulting from the diversity of drafting practices, one large company requires more than a dozen engineers to handle this one task.

Work on these new War Standards has already started. It is being financed by the War Production Board through an already existing government contract under which the ASA has since July, 1942 completed 88 standards of direct concern to the war effort and has under development some 68 more.

The military authorities have outlined the scope of the work to include civil, mechanical, electrical, aeronautical, and marine engineering, and the following subjects will be covered:

1. Abbreviations
2. Methods of indicating and specifying threads
3. Methods of lettering
4. Drawing forms and sizes
5. Graphical, diagrammatic and schematic symbols
6. Methods of indicating and specifying materials
7. Methods of indicating and specifying finishes
8. Methods of dimensioning and indicating tolerances
9. Methods of numbering drawings

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request.

A-C Generators

The Elliott Company has issued two 4-page folders which describe the construction features of the Elliott Type E and Type ED low-speed AC generators. These bulletins are illustrated with photographs and drawings and include a summary of the general features of these machines.

Care of Boiler Tubing

Republic Steel Corporation (Steel and Tubes Division) has published an informative card entitled "Care and Maintenance of Boiler Tubing." The text was prepared by the chief engineer of a leading boiler insurance company and constitutes an excellent reminder of the factors involved in the efficient care and operation of boiler equipment.

Castable Refractories

KAST-O-LITE, a product of the A. P. Green Fire Brick Company, is featured in an attractive 20-page booklet, just published, entitled "A Guide to the Uses and Advantages of Insulating Refractory Castable."

The merits and advantages of KAST-O-LITE are fully described, and admirable illustrations show typical furnace and still installations where this type of refractory may be used to affect economics.

Electronic Resistance Thermometer

Bailey Meter Company has published a 12-page bulletin (No. 230-A) featuring Pyrotron Electric Resistance Thermometers in indicating, recording and controlling models, for temperature ranges between the limits of minus 100 F and plus 1200 F. The instruments are said to be well suited for marine, mobile and other classes of severe service since no galvanometers or millivolt-meters are used.

Pressure Blowers

Buffalo Forge Company announces two new lines of pressure blowers designated as Type "CB" (Centrifugal Blower) and Type "CC" (Centrifugal Compressor). These units are described and illustrated in Bulletin No. 3553, which also contains complete data and ratings. The Type "CB" units have a capacity range from 200 to 5000 cfm and a pressure range from $^3/_4$ to 2 psi. The Type "CC" units range in capacity from 4000 to 75,000 cfm at pressures up to 4 psi.

Yarway Makes a Movie

"Yarway Makes a Movie" is the topic presented in the latest Yarway News bulletin received from the Yarnall-Waring Company. The purpose of the film is to show the engineering reason behind every Yarway product, to show typical applications of Yarway products in many industries, and to demonstrate the manufacture of these Yarway products. The bulletin tells about the features of this new film and how arrangements can be made for a showing.

Mechanical Flow Meters

Builders-Providence, Inc., has issued an 8-page bulletin (318B) featuring its line of "Flo-watch" mechanical flow meters. The mechanism and operation of these recording, indicating and totalizing instruments are described and illustrated and numerous installation diagrams are given illustrative of typical installations.

Rotameters

Cochrane Corporation has issued a new 16-page publication (R-100A) on Rotameters which, in addition to catalog material, contains helpful data on the selection of a Rotameter for any particular service. Specific gravities of gases and of various metals used in floats are given, together with formulas for converting water and air capacities to terms of other liquids and gases.

Rotary Blowers

Pottstown Blower Company, Division of Allen Billmyre Company, has issued an attractive 16-page bulletin (No. P100) which describes the principle of operation and the design and construction features of Pottstown rotary positive displacement type blowers and exhausters. The bulletin is profusely illustrated with sectional drawings, views of parts, assembly and installation views. Tables of capacity for both blowers and exhausters are also given.

Steam and Liquid Control Equipment

The 40-page 1945 catalog issued by O. C. Keckley Company, describes and illustrates its line of Steam and Liquid Control Equipment, which comprises precision pressure regulating valves, pump governors, temperature regulators, relief valves, float valves, self-cleaning strainers, water gages, gage cocks, illuminators and steam traps.

Steam Power Plant Planning

Planning information on 10,000- to 60,000-kw condensing turbines, surface condensers and auxiliaries, for building a new plant or adding generator capacity to an existing one, is presented in the new Steam Power Plant Planning Guide announced by Westinghouse Electric and Manufacturing Company.

Part 1 of the new 40-page booklet illustrates types of turbines, and charts turbine sizes and speeds. Part 2 on Performance Data covers basic operating conditions, including effect of deviation in pressures and temperatures on heat rates; regenerative feedwater heating; recommended condenser sizes, and condenser dimensions; condenser friction; impeller, propeller and axial type circulating pumps; and condensate pumps. Data are presented in chart and table form for easy selection.

Open Feed Water Heaters

Cochrane Corporation has just published "Cochrane Direct Contact Open Heaters" (No. 4091) which illustrates and describes different types of tray heaters, the jet heater, V-notch metering heater, also the convertible tray type heater which, by the insertion of additional trays, can be converted into a deaerator. The bulletin is profusely illustrated and shows various combinations of heaters with storage tanks.

Steam Tank Heaters

The Brown Fintube Company has issued a 2-page bulletin (No. 451) which describes its newly introduced Immersion Type Steam Tank Heater. The bulletin gives dimensions and weights of heaters for use with tank cars and trucks.

Synchronous Motors

The Elliott Company has issued a 4-page folder devoted to Elliott Type E low-speed synchronous motors. This bulletin describes the general features and construction details of these machines, with accompanying photographs and drawings.

Blowers and Turbines

L. J. Wing Mfg. Company has issued a condensed 8-page bulletin (SW-1) covering Wing Forced Draft Blowers, both turbine driven and motor driven, and Wing Auxiliary Turbines. Information includes photographs of installations, capacity curves, dimension tables and operating data.

Tube Cleaners

Thomas C. Wilson, Inc., has published a 6-page folder which gives a check list of steps to be taken before, during and after a tube-cleaning operation and a chart of Wilson Tube Cleaner sizes is given. An illustrated tabulation of motors and cutters is provided as an aid to the selection of appropriate equipment.